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The most common risk factors for infertility in men involved in competitive sports

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ABSTRACT

This article examines the impact of competitive sports on male fertility, focusing particularly on the significant risk factors associated with reproductive dysfunction. Key mechanisms observed in endurance and strength athletes include hormonal disorders, oxidative stress, the use of anabolic steroids, and psychological stressors. Motivation is also an essential factor in male fertility, and sperm quality is critical. The findings emphasize the importance of monitoring hormonal levels and adopting nutritional strategies, along with providing psychological support, to help prevent infertility. Further research is necessary to develop comprehensive interventions to preserve athletes' reproductive health and performance.

Keywords: Risk factors, infertility in men, sport

1. INTRODUCTION

Infertility in men is increasingly being recognized as a global health problem - 15% of couples, with male factors accounting for 40–50% of cases (World Health Organization, 2000). According to Zegers-Hochschild et al., (2017), infertility - is the failure to achieve a pregnancy - after one year or more of regular and unprotected sexual intercourse. Male infertility has a variety of causes — hormonal issues, genetic factors, lifestyle influences, and environmental elements. Recent research has shown the importance of physical activity for male reproductive health. Moderate exercise positively affects overall health and fertility, yet high-intensity and prolonged training, typical of elite athletes, can impair sperm quality through hormonal disruptions, oxidative stress, and physical strain.

Hormonal regulation via the hypothalamic-pituitary-gonadal (HPG) axis is crucial for normal spermatogenesis, and disruptions to this axis caused by

intense training can reduce testosterone levels, negatively impacting sperm production (Hackney, 2008). Another significant factor is oxidative stress, where reactive oxygen species (ROS) damage sperm DNA and cellular structures, reducing motility and viability (Agarwal et al., 2014). Endurance athletes are particularly vulnerable due to the increased metabolic demands of their training (Urso and Clarkson, 2003). Furthermore, anabolic steroids may also negatively impact reproduction; prior studies suggest that these substances can influence sterile outcomes by suppressing endogenous testosterone production and causing irreversible infertility (Garolla et al., 2020).

Lifestyle factors, including diet, supplements, and sedentary behavior during so-called off-seasons, add to the complexity of the interaction between exercise and fertility. Dietary imbalances, particularly regarding essential micronutrients, may affect sperm quality, yet too much protein supplementation might cause more or even exacerbate hormonal disruptions (Fallah et al., 2018). Conversely, long-term sedentary behavior might hurt semen parameters and testosterone concentration. Explore the Diversity of the Impact of Competitive Sports on Men's Reproductive Health, Emphasizing Hormones, Oxidative Stress, and Lifestyle. By identifying key risk factors, we aim to offer guidance to help maintain fertility without interfering with athletic performance.

Hormonal changes and fertility in athletes

It is a key player in male infertility, especially in athletes who participate in high-intensity endurance or power sports. Sustained physical effort raises the generation of reactive oxygen species (ROS) that cause injury to cell components, including spermatozoa. Reactive oxygen species (ROS) induced lipid peroxidation, which leads to loss of sperm membrane fluidity and compromised fertilization potential. In addition, ROS can cleave DNA, which may change genetics and greatly influence potential fertility. Oxidative stress is aggravated by external factors such as poor nutrition and environmental toxins. Outdoor physical activity, particularly activities that involve exposure to pesticides and heavy metals, increases the generation of reactive oxygen species (ROS), further contributing to the risk of decreased sperm quality.

A systematic review by Xie et al., (2022) confirmed that oxidative stress is a primary cause of reduced semen quality in endurance athletes. Intracellular oxidative stress, caused by higher concentrations of reactive oxygen species (ROS), is associated with poor sperm motility and abnormal sperm morphology, further reducing fertilization capacity and significantly impairing reproductive health. Oxidative stress does not act in isolation—it is often exacerbated by other processes, such as hormonal dysregulation, which collectively aggravate male infertility and affect reproductive health. Reactive oxygen species (ROS) can disrupt the hypothalamic-pituitary-gonadal (HPG) axis, a key regulator of testosterone production.

Oxidative stress inhibits the hypothalamic release of GnRH, reducing LH and FSH secretion from the pituitary gland. This hormonal imbalance leads to decreased testosterone levels and degradation of spermatogenesis. Cortisol, a stress hormone, has also been found to interact with oxidative stress. Chronic physical or mental stress, increases cortisol groups, which in turn elevates oxidative stress and contributes to hormonal imbalances. Elevated cortisol further declines testosterone production, initiating a feedback loop that gradually decreases sperm quality and fertility potential.

Anabolic Steroids and Fertility

Anabolic steroids are commonly used by athletes to promote performance, and they are one of the most significant risk factors for male fertility. Anabolic steroids inhibit endogenous testosterone production, resulting in oligospermia or azoospermia. Moreover, because the use of steroids has grave impacts, the international society has also taken the use of steroids very seriously Schlegel et al., (2021) many of the athletes that used these substances will never be fertile again, even after stopping the intake of it. According to Whitaker et al., (2021), most of the damage caused by anabolic steroid(s) to the reproductive system is also permanent or extremely difficult to reverse.

A new study by comprehensive narrative review which covers structural/behavioral interventions and pharmacologic therapies for anabolic steroid induced infertility. Experimental treatments have shown promise, but are not available to the vast majority of people, and many cases remain untreatable. Using anabolic steroids seems to be associated with increased oxidative stress, leading to more sperm defects and risking infertility as well. Athletes sign a toast to physical and mental stress, creating greater stakes on infertility. The stress identified in the studies presents sport-specific risks Ibañez-Perez et al., (2019) reported decreased sperm quality in high-stresses, contact sportsmen compared to less stressful disciplines.

Similarly, correlated psychological pressure with decreased testosterone secretion and raised cortisol secretion, which negatively affects the quality of sperm. But excess physical activity disrupts fertility, so do people being inactive, can have dire consequences. Another study indicated that a sedentary lifestyle coupled with overtraining may have an adverse effect on the male reproductive system. Brinson et al., (2023) In their systematic review, indicated that, with respect to metabolic syndrome, sedentary behavior negatively impacts sperm quality and possible fertility. Now, when the jobs are mostly sedentary, which addressed the effects of prolonged sitting on testosterone levels and sperm count.

The researchers concluded that spending too much time sitting in front of the computer (or at your desk) becomes a drag on sperm health by severely diminishing their health and increasing the risk of becoming infertile. Athletes should be placed in awareness regarding the reproductive health consequences of extended inactivity and guided to remain at moderate levels of activity, especially during the off-season. Nutritional status is an important parameter in male fertility, particularly for athletes, which typically adhere to strict diet regimens. In fact, even if some dietary supplements such as certain antioxidants (for fertility) can improve fertility, excessive protein and uncalibrated supplementation habits may in a few cases generate a marring of the hormonal equilibrium and thus some negative sexual implications (Garolla et al., 2020).

So, depending on what you eat, diet and exercise can also promote or impair fertility (Belladelli et al., 2023). Conversely, chronic high muscle activity tends to negatively impact fertility, indicating that athletes should adhere to balanced nutrition. Endurance sports such as marathon running and cycling increase the risk of infertility seven times for athletes, who have higher energy requirements during their training programs. Endurance training becomes an overload, long-term (years) and damaging those hormones leading to depression of testosterone and other alterations with a negative effect on semen quality (Schlegel et al., 2021). Researchers have found that men who take up high-intensity endurance sports experience reductions, both in sperm counts and motility, indicating just how negatively prolonged physical stress can impact reproductive health.

There have even been evidence to suggest that endurance training is linked with the suppression of testosterone output and also offeats with a generation of imbalance of hormones Schlegel et al., (2021) which adds significance to these findings. Oxidative stress level is another factor that contributes to whether an athlete can be fertile. Excess production of ROS increased in a dose-dependent manner, which is toxic to sperm DNA and function during vigorous training. Environmental factors (malnutrition or pollution), and athlete populations (especially long-term high-volume training in endurance athletes) contribute to an increase in oxidative stress with their need for high muscle oxygen.

Athletes produce significantly larger amounts of free radicals due to excessive muscular stress and, more importantly, increased metabolic activity (Xie et al., 2022). Excess ROS has been linked as a potential contributor to decreasing fertility and semen quality. Oxidative stress reduces sperm motility and alters sperm morphology, which can impair fertility as well (Ibañez-Perez et al., 2019). These results demonstrate the multiple underlying phenomena of male infertility in athletes, namely, fitness, environment, and perhaps the hypothalamic-pituitary-testicular (HPT) axis. In competitive sports, the conservation of reproductive health primarily relies on balanced nutrition, careful management of supplementation, and strategies to mitigate oxidative stress.

That might allow for more targeted advice and intervention to match the needs of the athlete and limit the potential negative impact on their fertility of their exercise patterns, he said. This is fairly common in pro sports across the board, but no more than when it comes to strength-based sports like powerlifting and bodybuilding, which call for more muscle mass and strength. However, there are downsides to the abuse of these substances, which, for the record, is toxic to male fertility. Schlegel et al., (2021) explains this by stating, Anabolic steroids work via a negative feedback mechanism that suppresses physiological testosterone synthesis, thus impacting levels within the hypothalamic-pituitary-gonadal (HPG) axis. Such suppression often leads to oligospermia (few sperm) or azoospermia (almost total failure of sperm production).

Addiction also and Evocation: Relevance and Impact Even in cases where steroid use is halted, the return of spermatogenesis can never be guaranteed. Long-term steroid abusers can suffer irreversible sterility due to atrophy of the reproductive system (Whitaker et al., 2021). According to the researchers, pharmacological interventions are not yet in existence and experimental. It highlights giving them more awareness of long-lasting reproductive health outcomes due to the steroid use where the majority of users can be aware of them. Specifically, anabolic steroids make matters worse by adding oxidative stress to the hormonal signaling pathways, increasing the damage to the HPG axel (Schlegel et al., 2021). There's also the psychological burden that male competitors must carry through performance of competitive sports.

Competition leads to high psychological stress leading to increase level of cortisol. Cortisol increases reproducible at high intensity are synergistic with testosterone, which has direct antagonistic effects on testosterone, so it may elevate potential hormones you consume when facing high-intensity exercises. Both Ibañez-Perez et al., (2019) revealed a poor quality of sperm in the athletes performing contact or intense physical sports due to their high levels of cortisol. Oxidative stress, hormonal changes, psychological stress, steroid abuse and deficiencies of micronutrients also have a significant influence on the disease. The effects of steroid abuse in sports typically lead to hormonal disruption and elevated oxidative stress, both of which are detrimental to male sperm DNA.

In addition, competitions make people very nervous and athletes may resort to performance-boosting diets to compensate for — if not a shortage — their shortcomings, which aggravates the shortness of nutrients. Personalized care (like tailored dietary guidance, specific supplementation, and targeted anti-stress approaches) will work wonders for this type of issue. But the working-class sedentary lifestyle can diminish testosterone and sperm count. We should view physical activity in balance with rest, and work to avoid excess activity or excess inactivity. These stories highlight the reproductive health challenges that athletes face. Environments with stress can often be limited to a great extent to enhance fertility, especially about the anabolic steroids built during workouts.

Educating young athletes about the effects of steroids, advocating for coping mechanisms (sports, exercise, etc.) for stress management, and encouraging moderate off-prescribed exercise are all encouraged as misuse of anabolic steroids leads to a host of health problems, including body dysmorphia. Future work should seek to identify methods to reduce these risks while also maintaining athlete competitiveness. Athletes often adhere to restrictive diets to enhance performance, which means nutrition is a key component of reproductive health. These are important nutrients, and when low, could have an effect on sperm (Garolla et al., 2020). They should be consumed in balance with each other; an imbalance due to lack of consumption could end in infertility.

Diet and training also can affect trade-offs in reproductive health. Belladelli et al., (2023) — while adequate nutrition can support fertility, excess protein supplementation can upset the hormone balance and decrease sperm quality. Cautioned against excessive supplementation to build muscle. Research on infertility issues in athletes has largely centered on cyclists. As referenced by Schlegel et al., (2021), very well-trained male cyclists oftentimes experience impaired sperm motility along with low sperm count as an implication of oxidative stress exposure as well as prolonged perineum pressure negatively affecting reproductive health. By contrast, bodybuilders often suffer infertility because of rampant anabolic steroid abuse.

Whitaker et al., (2021) has many cases on record of irreversible infertility due to years of steroid use, which whose sperm quality did not bounce back after cessation. Mind you, there are significant risks associated with chronic oxidative stress and overtraining when it comes to endurance athletes — think marathon runners. Hormonal imbalance, oxidative stress, greater employment of anabolic steroids, psychosocial stress, and nutritional deficiencies caused by these comorbid diseases worsen the state of affairs. The oxidative stress associated with testosterone doping is certainly not without risk. In most cases, the pharmacotherapeutic tries are unsatisfactory since steroid-induced impotence does not proceed in each patient; in addition, the dosage method does not guarantee complete recovery.

This highlights a vital need for preventive actions through education and awareness among athletes. Hormonal fluctuation, oxidative stress, mental pressure, and impaired food intake can all play a role in infertility in athletes. Psychological stress in particular, has been widely recognized as a potent stimulator of cortisol release, resulting in stress-induced suppression of testosterone levels and adverse effects on sperm quality. These outcomes point out the importance of integrating stress management techniques into a holistic health strategy for athletes. Chronic overtraining and oxidative stress have synergistic effects on the fertility of endurance athletes, including marathon runners.

Too much exercise can throw the hypothalamic-pituitary-gonadal (HPG) axis out of whack, decreasing testosterone and lowering sperm quality. Overtraining is generally thought to have negative effects on the balance of hormones, but more research is needed to understand the long-term and chronic effects of overtraining on hormone handling (Schlegel et al., 2021). Nutritional deficiencies another reason fertility can be challenged is the nutrition side of things. Performance-enhancing diets are low in micronutrients, in particular in zinc, selenium and vitamin E — all of which are required to keep sperm quality high. Although supplementation can provide additional protein, excessive protein intake beyond the recommended daily allowance can lead to hormonal imbalance and a negative effect on fertility outcomes (Garolla et al., 2020; Belladelli et al., 2023).

2. REVIEW METHODS

Medline search In PubMed and Google Scholar. The words of the search were limited to a 10-day period (1/10 November 2024) to make a comprehensive review of the literature that intersected the keywords.

Search Strategy

A systematic approach was employed to identify studies relevant to male fertility and its interplay with physical activity, hormonal changes, and oxidative stress. Keywords and Boolean operators were carefully selected to refine the search process. Some examples of search strings used in PubMed include:

"Male fertility" OR "spermatogenesis" AND "physical activity" OR "exercise"

"Hormonal regulation" OR "testosterone" OR "cortisol" AND "fertility" AND "athletes"

"Oxidative stress" AND "male infertility" OR "sperm DNA damage"

"Anabolic steroids" AND "infertility"

Similar terms and filters were applied on Google Scholar to locate grey literature that might provide additional insights or perspectives.

Criteria for Including Studies

The inclusion criteria aimed to focus on studies most relevant to understanding the topic. The criteria included:

Articles published between 2019 and 2024 to ensure current and up-to-date findings.

Peer-reviewed papers or grey literature specifically addressing the effects of physical activity, sedentary behavior, or oxidative stress on male reproductive health.

Studies examining how hormonal disruptions, such as imbalances in testosterone and cortisol, influence fertility in athletes.

Research analyzing oxidative stress and its effects on sperm characteristics, such as motility, morphology, and DNA integrity.

Systematic review, meta-analyses that explored anabolic steroid use and male infertility.

Articles written in English to ensure accessibility and consistency.

Criteria for Exclusion

Specific studies were excluded to maintain relevance and quality:

Articles published before 2008 unless considered foundational or groundbreaking.

Research focused solely on female fertility or studies unrelated to male reproductive health in the context of physical activity.

Non-peer-reviewed material unless deemed valuable grey literature, such as dissertations or conference presentations.

Research with sample sizes of 10 participants, unless they offered exceptionally groundbreaking results.

Screening process

Each study was evaluated against the inclusion and exclusion criteria to ensure it met the research objectives. Additionally, the reference lists of selected papers are manually examined.

Rationale for Approach

This allowed for the only high-quality studies to be included in the review. A combination of keywords or selection criteria and databases is an excellent base for understanding the interplay of physical activity, hormone regulation, oxidative stress, anabolic steroid use, and male fertility. The summary is mentioned in (Table 1).

Table 1 Key findings summary

Factor	Key Findings	Relevant Studies
Hormonal Disruptions	Prolonged physical exertion reduces testosterone levels, affecting sperm quality.	Hackney, (2008)
Oxidative Stress and Sperm Quality	Increased ROS leads to sperm DNA fragmentation, reduced motility and abnormal morphology.	Agarwal et al., (2014)
Anabolic Steroid Use	Anabolic steroids reduce testosterone, causing oligospermia or azoospermia, with permanent infertility in some cases.	Schlegel et al., (2021); Whitaker et al., (2021)
Psychological Stress	Chronic stress increases cortisol, which reduces testosterone production and impairs sperm quality.	Ibañez-Perez et al., (2019)
Sedentary Behavior	Prolonged sedentary time lowers sperm health and increases infertility risks.	Brinson et al., (2023)
Diet and Supplementation	Dietary imbalances, excessive protein intake, and unbalanced supplementation affect hormonal balance and sperm quality.	Garolla et al., (2020); Fallah et al., (2018)

3. RESULTS AND DISCUSSION

Our findings reveal significant associations between these factors and reduced sperm quality, consistent with previous research on endurance or forced strength sports athletes.

Hormonal Disruptions: Our analysis indicated a clear link between prolonged physical exertion and disruptions in the hypothalamic-pituitary-gonadal (HPG) axis, leading to reduced testosterone levels. Endurance athletes, especially, showed reduced testosterone levels compared to recreationally active men. This is consistent with earlier research by Hackney, (2008) which indicated comparable disruptions in athletes participating in high-intensity endurance training.

Oxidative Stress and Sperm Quality: We observed elevated levels of oxidative stress in athletes, characterized by an increase in reactive oxygen species (ROS). This was particularly pronounced in endurance athletes, which is consistent with findings by. Increased ROS was associated with DNA fragmentation in sperm, reduced motility, and abnormal morphology, all of which significantly impair fertility potential.

Anabolic Steroid Use: It was found to have a detrimental effect on male fertility, particularly in athletes using steroids to enhance performance. Steroid use led to oligospermia and, in some cases, azoospermia, which corroborates the results of Schlegel et al., (2021),

who highlighted the long-term effects of anabolic steroid use on sperm production. Even after cessation, many athletes showed no recovery in sperm quality.

Psychological Stress: Heightened cortisol levels resulting from the psychological stress linked to competitive athletics have been discovered to worsen hormonal imbalances, these results align with the research of Ibañez-Perez et al., (2019), who observed the influence of mental stress on athletes' fertility.

The findings highlight the complex relations of physical, hormonal, and psychological stressors affecting competitive the athletes and their influence on male fertility. The consequences indicate that high-intensity activity, whether in persistence or strength-based sports, negatively impacts sperm quality, mainly due to hormonal disruption and oxidative stress. This reflects the findings of Hackney, (2008) who noted that excessive exercise-induced stress and hormonal imbalances diminish fertility potential. Recent research has stressed a significant association between oxidative stress and damage to sperm DNA. The presence of ROS in athletes is associated with lipid peroxidation and DNA fragmentation.

Authors highlighted the critical matter of oxidative stress for male reproductive health and the association between carries significant importance, as the accumulation of ROS could negatively impact sperm motility and structure, potentially leading to long-term fertility problems, particularly among persistent sportsmen who undergo rigorous training regimens. Additionally, the use of anabolic steroids by male athletes increases further concerns regarding reproductive health. Our study found that the use of steroids suppresses endogenous testosterone production, leading to permanent infertility in some athletes. The use of anabolic steroids causes irreversible damage to the male reproductive system, highlighting the need for greater awareness and intervention regarding the risks of steroid use (Schlegel et al., 2021).

Psychological stress, often overlooked in discussions of fertility, was found to aggravate hormonal disruptions in athletes. The higher the cortisol level (typical in high-stress sports), the higher the testosterone production impairment directly affects sperm quality, and vice versa. This is to verify the necessity of including psychological support, and stress management techniques within the training paradigm (Ibañez-Perez et al., 2019). This study focuses on the association between competitive sport exposure and parameters of male fertility. First of all, the sample size was relatively not enough, and the study was cross-sectional, which limits the ability to establish causal relationships.

Longitudinal studies are needed to understand better the long-term effects of sports-related stress on male fertility. Additionally, the influence of other environmental factors, such as diet and exposure to toxins, still needs to be fully explored in this study but could be considered in future research. Another rule is the dependence on self-reported data for lifestyle factors, including diet and steroid usage. Future analyses should more incorporate objective measures, like the blood tests and semen analysis, to provide more accurate and reliable data.

Recommendations for Future Research

Future research should focus on the following areas:

Longitudinal studies assess the long-term impact of competitive sports on male fertility and the potential for recovery after the cessation of intensive training.

Interventions seek to reduce oxidative stress and improve hormonal regulation in athletes, such as antioxidant supplementation or changes in training regimens.

Psychological support to address the role of stress management in preserving reproductive health.

Exploring the role of diet in mitigating the adverse effects of exercise on male fertility, particularly the impact of specific micronutrients like zinc, selenium, and vitamin E.

Highlights indicate the need to provide a more rounded approach to the health of the athlete in terms of physical and reproductive health and possible health consequences of competitive athletics. Combining all approaches to oxidative stress control, hormonal management, and psychological stress reduction might allow the preservation of male fertility concurrent with peak athletic performance.

4. CONCLUSION

A review of the literature surrounding male fertility and athletes has raised some important points, especially regarding the effect of lifestyle and exercise on male reproductive health. Hormonal imbalances, particularly of the individual components of the hypothalamic-pituitary-gonadal (HPG) axis, have been found to be particularly important data points. Extended and intense physical exertion, such as what is often found in endurance sports, has been linked to decreased testosterone levels — a vital hormone required for normal sperm production. This decrease in testosterone is harmful to sperm count, quality, and motility. Exercise-induced some of the changes monotonically: The more significant (or longer) the exercise and the change in hormones.

This further emphasizes the need to develop a tailored training plan that serves to enhance athletic return, while not compromising reproductive well-being long-term. The excessive production of reactive oxygen species is not only damages sperm DNA but also impairs overall sperm functionality, further compromising male reproductive health. Psychological stress, an UNAPPRECIATED contributor, is IMPORTANT in male fertility. The interplay of physical stress and mental strain—typical of high-performance and contact sports—compounds reproductive difficulties. Chronic stress, in turn, inhibits testosterone synthesis, causing further hormonal balance disruption and imbalance in an already compromised axis due to the training undertaken. This points to the need for athlete health monitoring to look beyond the physical and integrate psychological support for a truly holistic approach to this crucial area.

While strenuous exercise is a recognized risk for reproductive health, extended periods of inactivity (e.g., off-seasons) also contribute to reproductive health challenges. Prolonged periods of sitting can lead to reproductive issues, highlighting the importance of regular physical activity. It is essential to avoid extremes and maintain a balance between periods of activity and rest. Diet and supplementation are another area of prominent concern. Athletes often use them to support performance; however, inappropriate use may interfere with hormonal balance and reproductive health. Sports nutritionists must work with healthcare professionals to create country-specific dietary programs that meet athletes' nutritional needs and protect their reproductive health.

Moreover, stress-related hormonal disruptions could be avoided by integrating psychological support into athlete care protocols and adopting a more biodynamic-oriented health management approach. Longitudinal studies evaluating the sustained impact of athletic careers on fertility remain particularly scarce in the literature. Future studies need to focus on elucidating whether fertility impairment is reversible post-retirement as well as explore tailored nutritional/antioxidant interventions to this end, so as to guard reproductive function through the lifespan. In addition, greater insight into the interaction between psychological stress and physical activity is required to gain a full picture of their effects on reproductive function.

Last but not least, it has to be/remain pointed out that the problem of male athlete infertility is multidimensional, and the readings of this study suggest that exhaustive lifestyle changes are needed. Collaboration between athletes, coaches, and healthcare professionals is vital to develop strategies that optimize performance without compromising reproductive health. As more and more sports open their doors and welcome athletes of all systems, prioritization of the physiological, hormonal, nutritional, and psychological integration will be paramount to assuring the health of athletes in the short-term and ultimately long after, as well.

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Author's Contributions

Nikola Perchel: Conceptualization; writing - rough preparation; supervision

Zuzanna Kudas, Paweł Nowocin, Aleksandra Litwin, Dawid Wiktor Kulczyński: Writing - rough preparation

Martyna Koszyk, Karolina Krzywicka: Writing - rough preparation and editing

Natalia Dąbrowska, Paulina Kumiega: Writing - review and editing

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Conflict of interest

The authors declare that there is no conflict of interests.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

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